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# Effect of Relative Humidity on Moisture Loss and Decay of Eastern Lettuce Prepackaged in Different Films

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# CONTENTS

| | Page |
|---|---|
| Summary | 3 |
| Introduction | 3 |
| Background | 4 |
| Methods | 4 |
| Results | 5 |
| Weight loss | 5 |
| Decay | 5 |
| Marketability | 7 |
| Discussion | 8 |
| Literature cited | 8 |

# EFFECT OF RELATIVE HUMIDITY ON MOISTURE LOSS AND DECAY OF EASTERN LETTUCE PREPACKAGED IN DIFFERENT FILMS[1]

By

M. J. Ceponis and J. Kaufman[2]

## SUMMARY

Film characteristics and ambient relative humidity greatly affected the amount of moisture lost from and the decay that developed in film-wrapped lettuce held for 5 days at 60° F. Less moisture was lost from but more decay developed in artificially inoculated lettuce when heads were wrapped in nonperforated polystyrene and minutely perforated polyvinyl chloride than when wrapped in 195-LSAD cellophane with three 1/4-inch holes per overwrap or in polyethylene, polyvinyl chloride, and polypropylene, multiperforated to 0.4, 0.4, and 1.3 percent of their surface area, respectively. Decay increased in all prepackaged lots when the ambient relative humidity was increased. More decay developed in shrink-film-wrapped lettuce when the overwrap was heat-shrunk than when it was not.

While less decay developed in the more extensively perforated film-wrapped lots, excessive moisture loss caused wilting in many heads held at 50 percent and in some heads held at 70 percent ambient relative humidity. No wilting occurred in any prepackaged lot at 90 percent relative humidity nor in lots wrapped in polystyrene or in minutely perforated polyvinyl chloride held at 50 and 70 percent relative humidity.

Despite more decay development, the nonheated polystyrene-wrapped and minutely perforated polyvinyl chloride-wrapped lots were more marketable than the more perforated film-wrapped lots at 50 percent relative humidity. At 70 and 90 percent relative humidity there were more marketable heads in the nonheated and more perforated film-wrapped lots than in the heated and least perforated film-wrapped lots.

## INTRODUCTION

Decay is the most damaging condition found in prepackaged head lettuce on the market. It is the prime cause of rejections of origin-wrapped lettuce shipments to the New York metropolitan area. In retail stores, decay of outer leaves almost exclusively determines the need for reconditioning prepackaged lettuce.

A number of plastic films of varying permeabilities are used to prepackage lettuce. Films retard moisture loss but some may cause excessive moisture buildups within the wrapper that favor decay. Moisture retention is directly related to the film's water vapor permeability, which can be greatly increased by perforating the film. However, the ambient humidity also affects the humidity within the package. This report presents data on shelf life studies of lettuce prepackaged in films of various permeabilities held at low, moderate, and high relative humidities.

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# BACKGROUND

Prepackaging of iceberg head lettuce in plastic films has increased steadily in recent years. At terminal markets, lettuce is prepackaged mostly in retail stores and in a few packing plants. Shipping point prepackaging accounts for only 5 or 6 percent of all lettuce marketed. This operation, however, is of interest to growers, shippers, and retail merchants. All stand to benefit from an origin-wrapped product that wins market acceptance. Growers and shippers would cut their transportation costs; retailers would eliminate the cost of in-store trimming (6, 9, 11, 13).[3]

Lettuce has been prepackaged at origin on and off since the 1930's but this practice did not become commercially significant until heat-shrinkable polystyrene was introduced as an overwrap for western lettuce in 1961. The film's water vapor transmission rate was believed high enough to overcome the problem of moisture retention associated with more impermeable films (1, 6). Other advantages of polystyrene were its comparatively low cost and its ready shrinkability under heat which facilitated wrapping (6, 9)

The inconsistent quality of prepackaged lettuce arriving at terminal markets in the early 1960's held up the quick market acceptance that was anticipated for the shrink-film-wrapped product (1, 10). Some shipments of shrink-film-wrapped lettuce were affected by excessive decay and discolored outer leaves. Some deterioration apparently resulted from heat damage to outer leaves incurred when the film overwrap was shrunk (5). To reduce heat damage, many packers lowered temperatures to the low side of the shrink range and produced a modified shrink wrap (3).

More recently there has been a resurgence of interest in origin-wrapped lettuce. Improved quality control, more uniform sizing of heads, and availability of new wrapping films have stimulated activity in prepackaging lettuce at origin (2, 11). Trade interest was considerably enlivened by a report which indicated that a total trade savings of $14 million could be achieved annually if all lettuce were wrapped at origin (4). This economy, however, is contingent on greater market acceptance of origin-wrapped lettuce.

Many merchants resist handling origin-wrapped lettuce because of past experiences with excessive decay. They doubt that decay can be adequately controlled in lettuce prepackaged a week or more before retail sale. Yet the potential benefits to be derived by successfully maintaining quality in prepackaged lettuce, especially origin-wrapped, warrant closer scrutiny of factors involved in decay development.

# METHODS

Four tests with the spring crop of eastern iceberg head lettuce were made in 1965 and again in 1966. New Jersey lettuce was prepackaged in seven tests; New York in one in 1965. To induce decay, all heads were sprayed with an aqueous spore suspension of a 7- to 10-day-old gray mold culture (Botrytis cinerea) just prior to wrapping. The gray mold organism was selected because of the increasing importance of the decay it causes on lettuce.

Six transparent films, including heat-shrinkable ones, were used to bag or overwrap the heads. The following films were used in 1965 and 1966:

1. Cellophane 195-LSAD, 1-mil gage, with three 1/4-inch holes perforating 0.0013 percent of overwrap for trimmed 6-inch diameter head.
2. Polyethylene bags, 1-mil gage, uniformly multiperforated from 0.35 to 0.40 percent.
3. Polyvinyl chloride A, 3/4-mil gage, uniformly multiperforated approximately 1.3 percent (used in two tests in 1965 and four tests in 1966).
4. Polyvinyl chloride B, 1/2-mil gage, minutely perforated 0.001 percent or less (used in two tests in 1965 and four tests in 1966).

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[3] Underscored numbers in parentheses refer to Literature Cited, p. 8.

5. Polystyrene, 1-mil gage, unperforated.

6. Polypropylene, 1/2-mil gage, uniformly multiperforated 0.35 to 0.4 percent (used in 1966 only).

The polyvinyl chloride B film was perforated by a commercial needle roller in a narrow band across the center of each wrap.

Except for the test with New York lettuce, the heads were harvested and prepackaged the same day. The New Jersey lettuce was harvested in the southern part of the State, trucked 55 miles to a Philadelphia packing plant where the shrink-film-wrapped heads were prepared, and then trucked another 70 miles to the Horticultural Crops Research Branch laboratory in Belle Mead, N.J., where the rest of the heads were prepackaged. The New York lettuce was harvested in Orange County, trucked 78 miles to the laboratory, held overnight under refrigeration, and then prepackaged the same way as the New Jersey lettuce.

All lettuce wrapped in the heat-shrinkable films, polystyrene and both polyvinyl chlorides, was prepackaged at the Philadelphia packing plant. The heads were trimmed to their cap leaves and grouped into lots of 12 heads each. An aqueous gray mold spore suspension was sprayed on the trimmed heads and six lots wrapped with each shrink film used in a test. Half of these lots were passed through a heat tunnel. The tunnel operated at 250°-295° F. depending on the kind of film used, lettuce pulp temperatures, and whether or not extraneous moisture was present on the outer leaves. The dwell time was 3 seconds and a modified shrink wrap was generally produced. The heated lots are designated by (S) in the tables.

The rest of the prepackaging was completed at the Belle Mead laboratory where all lettuce was stored and subsequently examined. After trimming and spraying with the fungal spore suspension, 12-head lots were bagged in polyethylene, overwrapped with cellophane or polypropylene, or left unwrapped. All of the prepackaged lettuce and one unwrapped lot of lettuce was placed in a single layer on shelves of walk-in refrigerated rooms kept at 60° F. and maintained at approximately 50-, 70-, and 90-percent relative humidities. The heads were left undisturbed for 5 days and then examined for weight loss, decay, and marketability.

## RESULTS

### Weight Loss

As expected, weight loss (which is largely moisture loss) of lettuce was greatly affected by the ambient relative humidity over the 5-day holding period at 60° F. (table 1).

Unwrapped lettuce lost much more weight than the film-wrapped lettuce. The average loss for an unwrapped head was 15.2 percent at 50 percent relative humidity and 12.6 percent at 70 percent relative humidity. The outer leaves of unwrapped heads wilted at these humidities. The average unwrapped head lost 4.1 percent at 90 percent relative humidity.

Plastic film wraps reduced the weight losses of heads held at the three ambient relative humidities. Nonperforated polystyrene and the least perforated film, polyvinyl chloride B, were most effective in retarding moisture loss with average losses ranging from 1.3 to 1.7 percent at 50 percent relative humidity to 0.3 to 0.4 percent at 90 percent relative humidity. No wilting was noticed in these films at any humidity. In contrast, lettuce wrapped in nonheated, multiperforated polyvinyl chloride A lost 5.5, 5.3, and 1.0 percent in the low, intermediate, and high humidities, respectively.

When weight loss exceeded 5 percent in a head, severe wilting of the outer leaves usually occurred. Besides the basic film permeability and perforation, head size and looseness of head also influenced the amount of moisture lost.

### Decay

Increasing the ambient humidity increased the amount of decay, especially in wrapped lettuce (table 2). Generally, decay was inversely related to moisture loss.

In unwrapped heads, there was no active decay on lettuce stored at 50 or 70 percent

Table 1.--Average weight losses in wrapped and unwrapped head lettuce after 5 days at 60°F under various ambient relative humidities

| Film wrap | Gage | Code | Degree of perforation | Tests[1] | Weight losses | | |
|---|---|---|---|---|---|---|---|
| | | | | | 50 percent relative humidity | 70 percent relative humidity | 90 percent relative humidity |
| | | | Percent | Number | Percent[2] | Percent[2] | Percent[2] |
| Polystyrene (S)[3] | 100 | -- | 0 | 8 | 1.3 | 1.0 | 0.3 |
| Polystyrene | 100 | -- | 0 | 8 | 1.7 | 1.2 | .4 |
| Polyvinyl chloride B (S)[3] | 50 | 22C92 | [4].001 | 6 | 1.5 | .9 | .3 |
| Polyvinyl chloride B | 50 | 22C92 | [4].001 | 6 | 1.7 | 1.1 | .4 |
| Polyethylene bags | 100 | A-101 | .35-.40 | 8 | 3.4 | 2.9 | .7 |
| Polypropylene | 50 | Y906B | .35-.40 | 4 | 3.3 | 2.8 | .9 |
| Cellophane | 100 | 195 LSAD | [5].0013 | 8 | 4.4 | 3.8 | 1.5 |
| Polyvinyl chloride A (S)[3] | 75 | 420 | 1.3 | 6 | 4.8 | 4.1 | .8 |
| Polyvinyl chloride A | 75 | 420 | 1.3 | 6 | 5.5 | 5.3 | 1.0 |
| None | -- | -- | -- | 8 | 15.2 | 12.6 | 4.1 |

[1] Twelve heads per test.
[2] Based on original weight of trimmed heads.
[3] Shrunk by passage through a heat tunnel.
[4] Or less.
[5] Based on three 1/4-inch holes in overwrap for trimmed head 6 inches in diameter.

Table 2.--Unmarketability in wrapped and unwrapped head lettuce after 5 days at 60°F under various ambient ralative humidities

| Film wrap | Tests | Unmarketable heads | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 50 percent relative humidity | | | 70 percent relative humidity | | | 90 percent relative humidity | | |
| | | Dehydrated heads | Decayed heads[2] | Total | Dehydrated heads | Decayed heads[2] | Total | Dehydrated heads | Decayed heads[2] | Total |
| | Number | Percent | Percent | Percent | Percent | Percent | Percent | Percent | Percent | Percent |
| Polystyrene | 8 | 0 | 21.9 | 21.9 | 0 | 31.2 | 31.2 | 0 | 39.6 | 39.6 |
| Polystyrene (S)[3] | 8 | 0 | 40.6 | 40.6 | 0 | 39.6 | 39.6 | 0 | 61.5 | 61.5 |
| Polyvinyl chloride B | 6 | 0 | 15.3 | 15.3 | 0 | 29.2 | 29.2 | 0 | 36.1 | 36.1 |
| Polyvinyl chloride B (S)[3] | 6 | 0 | 27.8 | 27.8 | 0 | 44.4 | 44.4 | 0 | 58.3 | 58.3 |
| Polyethylene bags | 8 | 12.5 | 11.5 | 24.0 | 2.1 | 11.5 | 13.6 | 0 | 32.3 | 32.3 |
| Cellophane | 8 | 35.4 | 6.2 | 41.6 | 10.4 | 12.5 | 22.9 | 0 | 29.2 | 29.2 |
| Polypropylene | 4 | 27.1 | 8.3 | 35.4 | 6.2 | 10.4 | 16.6 | 0 | 31.2 | 31.2 |
| Polyvinyl chloride A | 6 | 59.7 | 2.8 | 62.5 | 51.4 | 4.2 | 55.6 | 0 | 31.9 | 31.9 |
| Polyvinyl chloride A (S)[3] | 6 | 59.7 | 12.5 | 72.2 | 34.7 | 26.4 | 61.1 | 0 | 69.4 | 69.4 |
| None | 8 | 100.0 | 0 | 100.0 | 100.0 | 0 | 100.0 | 16.7 | 10.4 | 27.1 |

[1] Twelve heads per test.
[2] Decay was readily observed.
[3] Shrunk by passage through a heat tunnel.

relative humidity. Infections had begun in some heads but the consequent drying out and killing of the leaf tissues terminated the decay. At 90 percent relative humidity, only 1 in 10 unwrapped heads were decayed enough to warrant trimming at the end of the holding period.

In prepackaged heads, decay was generally related to the ambient relative humidity as well as to differences in the moisture retaining properties of the film wraps. Lettuce wrapped in the perforated films, polyethylene, cellophane, polypropylene, and nonheated polyvinyl chloride A, consistently had less decay than heads wrapped in the unperforated polystyrene and the minutely perforated polyvinyl chloride B films. When combined, decay in lettuce wrapped in perforated polyethylene, cellophane, polypropylene, and nonheated polyvinyl chloride A films averaged 7 percent at 50 percent, almost 10 percent at 70 percent, and just over 30 percent at 90 percent relative humidity. In the combined polystyrene-wrapped and polyvinyl chloride B-wrapped lots, decay affected 26 percent, 36 percent, and 49 percent of the heads held at low, intermediate, and high humidities, respectively.

Heat shrinking increased decay (table 2). The combined heated lots averaged 27, 37, and 63 percent decay at the 50, 70, and 90 percent relative humidities, respectively. At corresponding humidities, the combined nonheated, shrink-film-wrapped lots averaged 13, 22, and 36 percent decay. This would suggest that the outer leaf tissues were damaged or otherwise predisposed to decay. However little, if any, heat damage was observed. It is possible that the extra handling required in passing the heads through the heat tunnel was in some degree responsible for the increased decay.

## Marketability

Dehydration or decay determined the marketability of lettuce in this study. Russet spotting was not a factor. Heads were considered unmarketable if outer leaves were defective enough to require their removal at retail.

Unwrapped lettuce held at 50 and 70 percent relative humidity were unmarketable because of dehydration in 5 days at 60° F. Even at 90 percent relative humidity, more unwrapped heads were unmarketable because of dehydration than because of decay (table 2).

The marketability of most film-wrapped lettuce was limited more by decay than by dehydration. At 50 and 70 percent relative humidity, however, dehydration became a problem in the film-wrapped lots with high moisture loss (table 2). Decay limited marketability in all film-wrapped lettuce held at 90 percent relative humidity.

At 50 percent relative humidity, lettuce wrapped in the nonheated shrink films, polystyrene and polyvinyl chloride B, had the most marketable heads, 78 percent and 85 percent, respectively. The relative impermeability of these films to water vapor prevented the heads from becoming dehydrated. Comparatively less decay but more wilting occurred in lettuce wrapped in the more perforated films, especially in the polyvinyl chloride A lots. The polyethylene-bagged lettuce had the most marketable heads, 76 percent, of the more perforated film-wrapped lots held at the low humidity (table 2).

At 70 percent ambient relative humidity lettuce wrapped or bagged in cellophane, polyethylene, and polypropylene was more marketable than lettuce wrapped in polystyrene and polyvinyl chloride B films. While there was some dehydration in the former lots, there was considerably more decay in the latter lots. Unmarketable heads in the polyvinyl chloride A-wrapped lots held at this humidity exceeded 50 percent, mostly due to dehydration.

At 90 percent relative humidity decay caused the deterioration in all prepackaged heads that became unmarketable. The least marketable lots were those wrapped in shrink films that were heated. The more marketable lots were those wrapped in the more extensively perforated films that were not heated.

## DISCUSSION

When lettuce is prepackaged in plastic films, wilting and shedding of leaves are reduced (6, 7, 8) but decay development is enhanced. Prepackaging will normally prolong the shelf life of lettuce, especially at the retail store where moisture loss of unpackaged produce is a big problem. Dehydrating humidities ranging from 45 to 60 percent were most often found in New Jersey supermarkets visited the year around.

Lettuce quality is more effectively controlled by prepackaging at the terminal market, but prepackaging at origin is more economical. Because high humidities usually exist within cartons of lettuce in refrigerated transport (12), film-wrapped lettuce may decay if leaves are mechanically or physiologically injured. Normal transit temperatures will prevent or retard most decays, but some diseases such as gray mold rot, will develop even at 34° F.

Decay in our tests was probably higher than would normally be found because we used artificial inoculations and held the lettuce at relatively high temperatures. Such high incidences of decay would normally reflect unusual situations. Whether decay assumes important proportions under natural conditions is determined more or less by such factors as weather at harvest, lettuce vigor and condition, microbial contamination, mechanical injuries, and temperatures and humidities encountered during marketing. Moisture loss under commercial conditions would also probably be somewhat less than was found in our tests where the lettuce was subjected to a temperature of 60° F. for 5 days.

If the decay potential is serious, our tests indicate the use of a prepackaging film with greater water vapor permeability than that found with polystyrene or the minutely perforated polyvinyl chloride film we used. The degree of permeability must take into account the relatively low humidities that are commonly encountered in retail. Ordinarily, ventilation of relatively impermeable films such as polyethylene and polypropylene with small, evenly spaced perforations up to 0.35 percent of the surface area should adequately control moisture loss in heads under most retail conditions.

Decay increased when lettuce overwraps were shrunk by heat. Shrink films greatly expedite the wrapping operation and the packer will have to decide whether this advantage outweighs the risk of added decay (3).

Decay development in prepackaged lettuce is best controlled by (1) proper trimming of heads, which reduces microbial contamination; (2) careful handling throughout marketing, which reduces bruises--the common sites of infection; and (3) rigid application of recommended precooling and refrigeration practices at all levels of marketing.

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